The production and consumption of basalt artefacts in the southern Levant during the 5th-4th millennia BC: a geochemical and petrographic investigation

Graham Philip[1] and Olwen Williams-Thorpe[2]
[1]Dept. of Archaeology, University of Durham, South Road, Durham DH1 3LE, U.K. Email: graham.philip@durham.ac.uk
[2]Dept of Earth Sciences, The Open University, Milton Keynes, MK7 6AA, U.K. Email: o.williams-thorpe@open.ac.uk

Abstract

Recent analytical work has revealed the complex, multi-component nature of assemblages of many categories of material occurring at 5th-4th millennium BC sites in the southern Levant. In an attempt to better understand the role of basalt artefacts within the procurement of resources as a whole, petrological and geochemical analyses using WDXRF were carried out on c. 50 samples of geological and artefactual basalt. Investigations concentrated upon three key issues:

1. Comparison of the nature of the artefactual basalt occurring at selected Chalcolithic - EBA I sites located in various regions of the southern Levant.
2. The exploration of possible subdivisions within the production of basalt artefacts, through the investigation of the relationship between rock types and artefact forms.
3. The identification of specific compositional groups within the artefactual assemblage, and the relationship of these groups to likely source areas.

The results reveal the complexity of basalt supply and consumption during this period, and indicate the existence of both regional and typological patterning.

Introduction to the study*

A number of recent studies have emphasized the role of specialized craft production and the acquisition of non-local raw materials as a key factor in the development of social complexity in the southern Levant during the fifth-fourth millennia BC (Joffe 1993; Levy 1993, 1995a). These generally argue for a linkage between authority over the production and distribution of certain categories of materials, and the development of increasingly hierarchical networks of social, political and economic control (but note Rosen's [1993] more sceptical position). However, recent research in other areas of the ancient Near East has demonstrated that such generalized frameworks are an oversimplified version of reality, and it is becoming apparent that different aspects of specialist craft production were variably connected with such power structures. In practice, substantial areas of specialized craft production appear to have operated outside spheres of elite domination (*e.g.* Stein and Blackmann 1993; Wattenmaker 1994).

Until recently, however, our ability to undertake such detailed analyses using data from the southern Levant has been hindered by our limited understanding of patterns of resource acquisition and distribution, in particular by our inability to characterize adequately many basic materials. Fortunately, the last few years have witnessed significant advances in the recognition of specific sub-groups within broad categories of material: ceramics (Commenge-Pellerin 1987, 1990; Goren 1995; Greenberg and Porat 1996), copper (Levy and Shalev 1989; Hauptmann *et al.* 1992; Shalev 1994; Tadmor *et al.* 1995; Rehren *et al.* 1998), silver (Philip and Rehren 1996, Rehren *et al.* 1996), and chipped and ground stone (Rosen 1997; Philip and Williams-Thorpe 1993). This new, richer database should provide the evidential basis for more sophisticated treatments of procurement and production, and the present report is intended to advance the potential contribution of studies of ground stone artefacts to the investigation of these issues.

Rosen (1997: 113-115) has recently made the point that the chipped stone evidence indicates the coexistence of locally-based and longer-range procurement systems, the various components of which demonstrate differing spatial extents and degrees of specialization. Thus the chipped stone assemblage from a single site or phase is a composite, the various components of which may well have been acquired through rather different sets of socio-economic relationships. He has further argued that there is little contextual evidence to connect chipped stone production in the southern Levant with elite control of resources. In fact, the growing complexity of the evidence for resource procurement and craft production in the Levant during the 5th-4th millennia BC, as underlined by new analytical studies (see above), argues against any resort to a monolithic notion of craft specialization, with its attendant socio-political overtones.

The notion of multiple resource acquisition systems receives support from recent archaeometallurgical studies. The coexistence during the Chalcolithic of two different compositional types of copper, employed for utilitarian and prestige metalwork respectively, has been known for some time (Shalev and Northover 1987, 1993; Tadmor *et al.* 1995). However, recent work (Rehren *et al.* 1998) has shown that the copper utilized at EB I Tell esh-Shuna was unlikely to have come from the same sources as the low impurity copper, which on present evidence, appears to characterize EB I production elsewhere. Equally, instances from the southern Levant of fourth millennium BC silver containing a significant admixture of gold, presumably through mixing during recycling (Rehren *et al.* 1996), argues for some variability in the mechanisms through which this metal was acquired. The implication is that complex, multiple-sourced procurement systems were rather more common than has been assumed hitherto. This suggestion appears consistent with research in other regions

Note: The chronology used here is Chalcolithic late 6th millennium BC–ca.3600 BC, and Early Bronze Age I ca.3600-3000 BC and is based upon calibrated radiocarbon dates (Joffe and Dessel 1995 and unpublished dates from excavations at Tell esh-Shuna).

which has highlighted the coexistence of multiple procurement systems, within what researchers have traditionally considered as single categories of material (Perlès 1992; Tykot 1996).

The recognition of the complex processes through which an assemblage is created has implications for our understanding of ground stone production. The very definition of units of analysis such as "ground stone industry", denies the fact that our analytical categories are a function of contemporary archaeological procedures, which may diminish their essentially multi-component natures. The fact that archaeology as a discipline has found it convenient to recognize a single category "ground stone" should not lead us to presume the existence of a corresponding conceptual category among user communities (*cf.* Barrett's [1994: 86-97] discussion of the supposed Beaker complex in European prehistory).

The above discussion has important implications for our understanding of ground stone, in particular the place of basalt in artefact production. Like flint, basalt is not inherently scarce in the Levant, making it unlikely that the material possessed any great potential for "exclusivity". However, basalt is heavy, rendering difficult its transportation in significant quantities, a point exacerbated by the uneven distribution of outcrops throughout the region (Williams-Thorpe and Thorpe 1993: Figure 1). For these reasons alone, some communities' access to basalt would have almost certainly been mediated through social relationships, perhaps centring upon the exchange of finished, or partly manufactured products, rather than raw materials.

Basalt artefacts in the Levant: research problems and sampling strategy

The arguments advanced above indicate that discussion framed in terms of a single basalt acquisition network is unlikely to do justice to the potential complexity of procurement systems functioning during the fifth and fourth millennia BC. The problem has been how to address these issues in the context of ground stone artefacts. The fact that south Levantine volcanics of Miocene to Pliocene age are generally quite similar petrographically, being typically characterized by the presence of iddingsitized olivine, renders it hard to distinguish on a petrographic basis between the material occurring at many of the potential basalt sources in the region (Amiran and Porat 1984). A possible way forward appears to lie in geochemistry, the value of which as an analytical technique for studying the provenance and distribution of ancient basalt artefacts has already been demonstrated by Williams-Thorpe and Thorpe (1993). However, most published work dealing with the east Mediterranean has examined material from later periods, during which the acquisition of basalt millstones involved the transport of suitable rocks over quite long distances (Williams-Thorpe 1988; Williams-Thorpe *et al.* 1991; Williams-Thorpe and Thorpe 1993). Such patterns of movement are susceptible to analysis by techniques able to discriminate between the various volcanic rocks at an inter-regional scale.

However, fifth and fourth millennia BC procurement systems appear likely to have operated on an *intra-regional* scale, the investigation of which requires the ability to distinguish *between* various basalt sources *within* the southern Levant. An initial provenance study of Jordanian basalt artefacts (Philip and Williams-Thorpe 1993) revealed the value of trace element patterns as a means of achieving this end, by comparing the geochemistry of vessels recovered from sites located south and east of the Dead Sea, with those from Sal on the north Jordan plateau, and was thus able to demonstrate the existence of geographically distinct production centres, each using relatively local rocks.

This initial investigation raised a number of points (Philip and Williams-Thorpe 1993: 59-61) which the current study seeks to address. The main elements include:

1. The possibility that there may have existed a multi-component basalt industry in which a distinction existed between the production of bowls and other forms of artefact.
2. The proposition (see Gilead and Goren 1989: 12) that the large Chalcolithic site of Teleilat Ghassul, located near to the Sweimeh outcrop, was a production centre for basalt artefacts.
3. The possibility that the basalt found on sites in southern Palestine may have originated, not in Galilee as has generally been supposed (*e.g.* Amiran and Porat 1984), but in southern Jordan, a suggestion which, given the evidence for the role of southern Jordan as a major regional copper source (Hauptmann *et al.* 1992; Shalev 1994; Adams and Genz 1995), has important ramifications for wider patterns of socio-economic interaction.

The present investigation is intended to address these questions and to define more clearly those areas critical for the future development of research into the role of basalt in the past in this area. This is achieved through an expansion of the initial database to encompass sites in two additional areas: the Jordan Valley (one site each at the northern and southern ends, both located close to basalt sources) and two sites in southern Palestine, each located more than 50km from the nearest basalt outcrop and thus requiring the procurement of raw material from relatively remote sources (Figure 1). Improved coverage of geological sources is provided by specimens collected from outcrops on the east (Jordanian) side of the north Jordan Valley. Provenancing draws on source discrimination for the Levant established by Williams-Thorpe and Thorpe (1993) and Williams-Thorpe *et al.* (1991), and extended by samples in Philip and Williams-Thorpe (1993), modified to accommodate the new data described above.

Recent petrographic work

Despite the pessimism expressed by Amiran and Porat (1984) in this regard, research during the last decade has identified several groups of material sufficiently distinctive

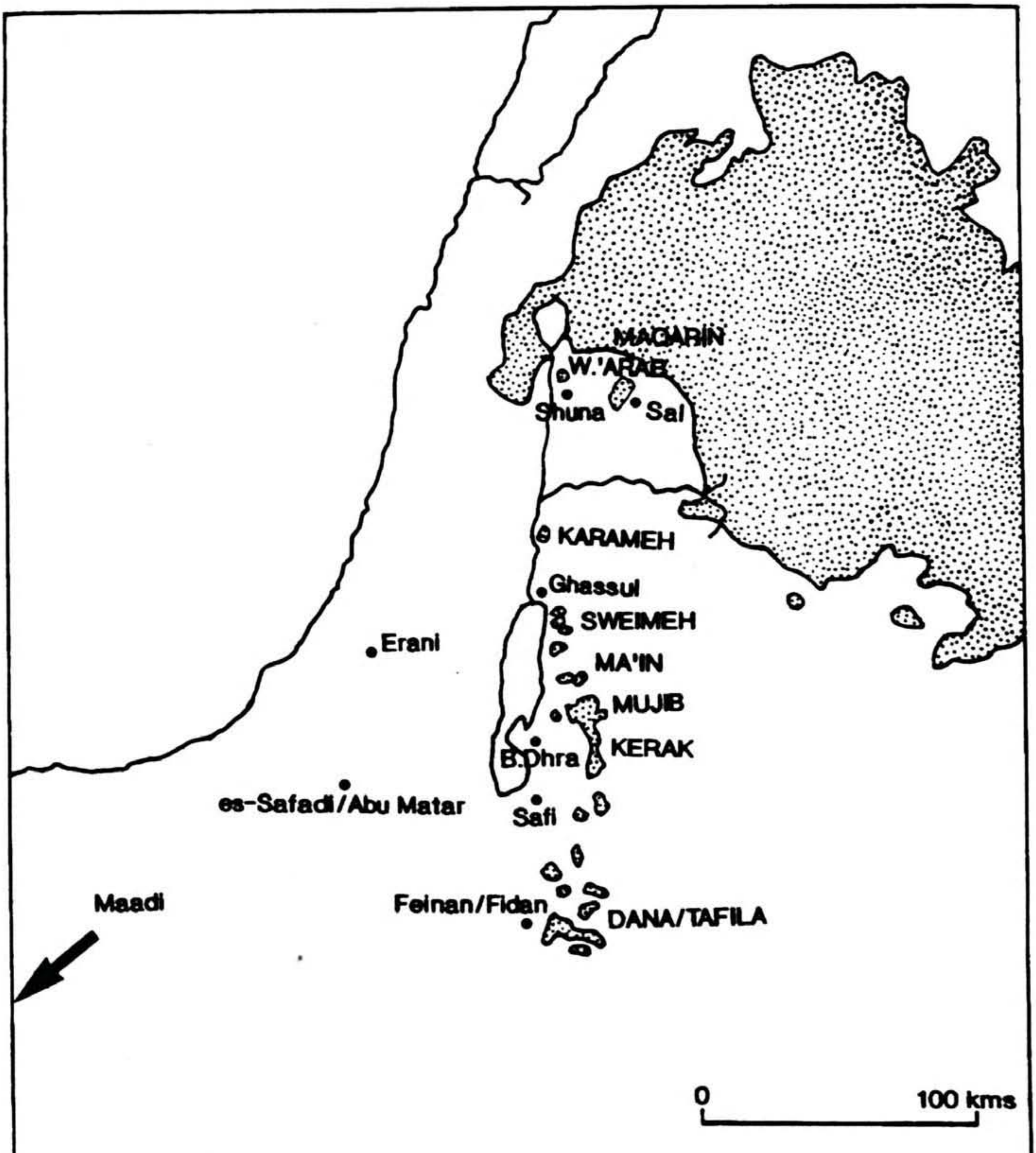


Figure 1: Map showing the extent of Miocene to Quaternary volcanics in the southern Levant. Sites from which artefactual basalts have been analysed are marked by a black dot with names in lower case; approximate location of geological samples marked in upper case. WADI 'ARAB denotes also samples collected from North of Shuna and Adasiyeh as all three outcrops are located within the same general area.

to be recognized on the basis of petrology. These include the Quaternary volcanics of the Jaulan which have typically fresh olivine (Williams-Thorpe and Thorpe 1993) and the nepheline basanites from sources in south-western Jordan (Ibrahim 1987; Ibrahim and Saffarini 1990). Researchers have also identified the production of stone vessels in a distinctive black sedimentary rock, phosphorite, which is believed to have originated in south-central Palestine and which is superficially similar to basalt (Gilead and Goren 1989; Goren 1991). This material appears to have been employed in the manufacture of some 15-20% of the "basalt" vessels occurring at sites in the northern Negev, the Shephelah and the southern part of the West Bank, although it has been identified at locations as far east as Teleilat Ghassul in the Jordan Valley (Goren 1991; see also below).

Some clarification of the terminology in use is required at this point. In the following discussion a distinction is made between two broad categories of basalt artefact. The first is a range of finely made, often decorated bowls, with flat bases and flaring sides (see Braun 1990), which, with rare exceptions, appear in basalt throughout the southern Levant. (Note that this group is not co-terminus with "stone vessels" as defined by Wright [1992: 75-77], which includes a far broader range of artefacts.) Bowl production appears to have been restricted to fine-grained rocks, and would have required a significant input of time and effort. On present evidence bowls occur in both domestic and mortuary contexts and it is hard to assess whether they should or should not be considered "prestige" artefacts (see Braun 1997: 100). However, the fact that bowls feature in the artefact repertoires of sites with no ready access to basalt sources, indicates the existence of at least a medium-range procurement system which should be susceptible to analysis.

The second group includes heavy processing tools such as grinders and pounders as well as vessels not fitting the specific criteria for bowls. Basalt is the predominant material for the production of such artefacts at sites in northern Palestine and Transjordan such as En Shadud, Yiftah'el, Jawa and Tell esh-Shuna (Braun 1985: 89, 1997: 100-101, Betts 1991: 154; unpublished material from Tell esh-Shuna) all in locations offering reasonable access to basalt sources. However, at sites located further from outcrops of good quality basalt, Jericho for example, or sites in southern Palestine, there is evidence for a greater use of alternative, locally available rocks (Dorrell 1983: 561-562; Braun 1997: 101 note 5). In order to maximize limited resources, it was decided to examine only a small selection of artefacts in this category at this stage. Our investigation was focused upon rock utilization in two locations, Teleilat Ghassul and the Wadi Feinan, where basalt is locally available, but where preliminary investigation (Philip and Williams-Thorpe 1993: 60-61) had suggested the use of significant quantities of non-local material.

Review of potential source areas

Volcanic rocks of basic composition are widespread in the east Mediterranean area. Those of the Levant have been described in summary by Williams-Thorpe and Thorpe (1993) and have been discussed in detail in many publications, notably Barberi *et al.* (1980), Bender (1968), Burdon (1959) and Van der Boom (1968). Regional and analytical studies include Goren-Inbar *et al.* (1986), Ibrahim and Saffarini (1990) and Saffarini *et al.* (1985, 1987). The volcanics of the east Mediterranean region can be broadly divided petrogenetically and therefore chemically into two types:

1. within-plate volcanics of the Levant and Egypt, and
2. subduction-related and continental collision zone volcanics in Anatolia and Greece.

Outside the Levant, basic composition volcanics occur in Egypt, west and east of the Nile Delta. These rocks, at 125-20Ma, are older than many of the Levant volcanics and comprise basalts of tholeiitic tendency typically with iddingsitized olivine (El-Hinnawi 1965; El-Hinnawi and Abdel Maksoud 1968, 1972). Calc-alkaline volcanic associations containing some basic members occur in central and western Anatolia, in mainland Greece and in the islands of the Hellenic Arc (summary of characteristics and literature in Williams-Thorpe and Thorpe 1993).

Figure 1 shows the extent of younger (Miocene to Quaternary) volcanics, including very widespread outcrops of alkali olivine basalts in south Syria and northern Jordan (As Shamah plateau), around Lake Tiberias, and east and south of the Dead Sea. Small outcrops of very altered basalt in the Negev have been dismissed as unsuitable for vessel manufacture (Philip and Williams-Thorpe 1993 referring to Amiran and Porat 1984). The inner coastal plain of Palestine contains small outcrops near Hulda and Yesodot, but these are described respectively as "mixed with cultivated soil, ...strongly weathered" and "a 1m intercalation in marlstone of olivine basalt...amygdaloidal, strongly weathered" (Gvirtzman and Buchbinder 1969), and are therefore also very unlikely sources of vessel or grindstone raw material. A small outcrop at Karameh north of the Dead Sea (Figure 1), analysed by Philip and Williams-Thorpe (1993), is also composed of friable and altered basalt (Philip and Williams-Thorpe 1993, referring to Wright *et al.* in press; Barberi *et al.* 1980), deemed unsuitable for vessel manufacture.

The Levant volcanics of Miocene to Pliocene age are typically characterized by the presence of iddingsitized olivine, while younger (Quaternary) products have typically fresh olivine. The area to the south-east of the Dead Sea (Dana, Tafila area) contains outcrops of basanites and nephelinites (Ibrahim and Saffarini 1990).

Description of the samples

Fifty fragments of archaeological artefacts from nine sites in Jordan, Palestine and Egypt were examined at the Open University in order to determine rock types, to suggest geochemical groupings and to investigate geological provenance. (The locations of the sites are shown on Figure 1). Artefact types included grinders, vessels and a fragment from a stone ring. Forty nine of the samples are of basic igneous rock (basalts or closely related types), and one sample (J4) was identified as a bioclastic sedimentary rock

Table 1: Archaeological samples analysed.

Ref. no.	Site	Artefact type	Thin Section
J1	Ghassul	Grinder/rubber fragment	*
J2	Ghassul	Grinder/rubber fragment	*
J3	Ghassul	Grinder/rubber fragment	*
J5	Ghassul	Fragment from foot of fenestrated vessel	*
J6	Ghassul	Vessel, fragment of foot	*
J47	Ghassul	Fragment from foot of fenestrated vessel	*
J8	Maadi	Stone ring	
J10	Wadi Fidan 4	Fragment from rim of curve-sided vessel	*
J11	Wadi Feinan site	Fragment of rim of vessel	*
J12	Wadi Feinan site	Fragment of rubber type tool	*
J13	Tell Erani	Vessel with pedestal base, fragment	
J15	Tell Erani	Rim fragment of vessel bearing knobs	*
J16	Tell Erani	Fragment of thick base of vessel	*
J17	Tell Erani	Fragment of four handled vessel	
J26	Shuna	Vessel, fragment of base	*
J27	Shuna	Vessel, fragment of base	*
J29	Shuna	Vessel, rim fragment, curve-sided	*
J31	Shuna	Vessel, rim fragment	*
J32	Shuna	Mortar type vessel, rim to base section	*
J56	Shuna	Vessel rim fragment, edge almost flattened	*
J57	Shuna	Vessel rim, bevelled edge, flaring out	*
J58	Shuna	Vessel rim, plain	*
J35	Abu Matar	Vessel	
J38	Abu Matar	Vessel	*
J39	Abu Matar	Vessel	
J40	Abu Matar	Vessel	
J42	es-Safadi	Vessel	*
J44	es-Safadi	Vessel	*
J45	es-Safadi	Vessel	
J46	es-Safadi	Vessel	
J51	Safi	Vessel rim fragment with horiz. ribs in relief	*
J52	Safi	Vessel rim fragment	*
J53	Safi	Vessel rim fragment	*
J54	Safi	Vessel rim fragment	*
J55	Safi	Vessel rim fragment, possibly bevelled	*

which matches descriptions of phosphorite given by Goren (1991). Eight new geological samples collected from outcrops on the eastern side of the north Jordan valley, in the vicinity of the Wadi' Arab and at Maqarin in the Wadi Yarmouk (Figure 1) were also examined to eliminate lacunae in the corpus of outcrop analyses available for provenancing.

Thirty five of the archaeological samples were selected for chemical analysis by wavelength-dispersive x-ray fluorescence analysis (WDXRF), and these are listed in Table 1. The selection was limited by sample size, as some were too small for analysis, but includes visually representative rock types from all the sites included in the study. In the case of those samples for which sufficient material remained after chemical analysis, standard petrological thin sections were also prepared (Table 1). The new geological samples were analysed and thin-sectioned in the same way as the archaeological samples, and are listed in Table 2.

Archaeological Samples

Forty-nine of the archaeological samples are grey, fine-grained, finely vesicular basic rocks with altered olivine (orange-red iddingsite) often visible in hand specimen, together with feldspar crystals and sometimes pyroxenes. In thin section they typically comprise a holocrystalline assemblage including plagioclase feldspar, clinopyroxene, opaques (iron titanium oxides and others, not distinguishable in transmitted light), and olivine variably altered (sometimes completely altered) to iddingsite. Ophitic and sub-ophitic texture is very common. The additional sample, as noted above, was identified as phosphorite, a dark coloured sedimentary rock (see below).

Five of the igneous samples differ slightly from the remainder. Three samples from Ghassul (J1, J2 and J3) have phenocrysts of olivine, mainly fresh with iddingsite rims, and of pyroxenes sometimes in clusters, with smaller feldspars, pyroxenes and opaques set in a cryptocrystalline matrix. J10 from Wadi Fidan 4 (Adams and Genz 1995) is a black basic rock with fresh olivine visible in hand specimen. In thin

Table 2: Geological samples analysed

Ref. No.	Locality	Collection details
J18	N. of Shuna	Between Shuna and Adasiyeh, outcrop above and to E. of road
J19	N. of Shuna	Between Shuna and Adasiyeh, outcrop above and to E. of road
J20	Adasiyeh	Outcrop immediately E. of Adasiyeh village
J21	Adasiyeh	Outcrop immediately E. of Adasiyeh village
J22	Wadi 'Arab	Flows just N. of Wadi Arab dam
J23	Wadi 'Arab	Flows just N. of Wadi Arab dam
J24	Maqarin	Maqarin flow, S. side of Wadi Yarmouk
J25	Maqarin	Maqarin flow, S. side of Wadi Yarmouk

section it is distinctive because of the lack of feldspar phenocrysts, and it has phenocrysts of nepheline, olivine (not altered to iddingsite) and pyroxene in a mainly cryptocrystalline matrix. J12 from Wadi Feinan is less distinctive but has larger pyroxenes than the typical type described above, with olivine plus iddingsite within a finer matrix of feldspars, pyroxenes and opaques.

Geological samples

Samples collected from outcrops located immediately to the north of Tell esh-Shuna (J18, J19), Adasiyeh (J20, J21) and Wadi 'Arab (J22, J23) are grey, non-vesicular to slightly vesicular basic rocks with iddingsite, olivine, pyroxene and feldspars visible in hand specimen. In thin section they comprise a holocrystalline assemblage of plagioclase iddingsite, and opaques. Ophitic and sub-ophitic texture is present. These samples are similar in petrographic characteristics to the majority of the archaeological samples described above. However, these characteristics are common in basalts, in particular in alkali basalts, and are not likely to be diagnostic of source. Samples from Maqarin located further to the east in the Wadi Yarmouk (J24, J25) differ slightly in having mainly fresh olivine and pyroxene with smaller feldspars, pyroxenes, olivines and opaques within a cryptocrystalline matrix.

Chemical analysis

Method

The analysed samples were broken into small (1-2cm) pieces so that one piece could be removed for a thin section and, wherever possible, a piece reserved for future reference. About 20g of each sample was crushed using an agate ball mill, and powder pellets prepared for analysis. Several samples were unsuitable for crushing in the automated ball-mill because of small size or inhomogeneous texture, and these were crushed by hand in an agate pestle and mortar.

Analysis for 18 trace elements and for Fe and Ti was done by WDXRF following the principles described by Potts and Webb (1992). Precision of the method is given in Govindaraju *et al.* (1994) and is between 0.5-6.0% (1 sigma) for trace elements, except for Pb and Th (12% and 19% respectively). Accuracy was monitored by comparison with international reference materials and is within or near precision except for atypical abundances. Fe and Ti values obtained for reference materials indicate precision and accuracy within the range for the main group of trace elements (*i.e.* not including Th and Pb).

Results

Chemical analyses of archaeological samples arranged according to analytical groups which are discussed below, and of new geological samples, are given in Tables 3 and 4 respectively.

Grouping and provenancing of archaeological samples

Provenancing was carried out following the guidelines in Williams-Thorpe and Thorpe (1993: especially 280-281). These lay emphasis on stable elements, *i.e.* those resistant to mobilization and alteration within igneous rocks, and which are particularly diagnostic of rock tectonic setting and original magma composition, and therefore of source locality. Such elements include Ti, Zr, Nb, and Y. The analysed samples are generally unweathered so that abundances of relatively mobile elements such as Rb and Sr are still likely to be meaningful in terms of sample origin.

Tectonic type and general source area

All the samples analysed fall within the range of within-plate character basalts according to the Ti/Zr and Zr/Nb based criteria of Pearce (1982). This excludes an origin within the plate margin-related rocks of Anatolia and Greece. The samples lie outside the high Ti/Zr ratio field of Egyptian basalts defined in Williams-Thorpe and Thorpe (1993: 294). By process of elimination, this implies that the samples originated within the Levant volcanics (Jordan, Palestine, Syria). As noted above, the Levant volcanics cover a large geographical area; the Jordan plateau alone covers an area of more than 65000km^2 (Figure 1). We now have at our disposal several hundred analyses of source rocks from the Levant volcanics and can make some generalizations about chemical and petrographic characteristics of certain geographical areas (Williams-Thorpe and Thorpe 1993).

Table 3: Chemical analyses of archaeological samples and of likely source outcrops

Sample ref.	Element/oxide	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	U	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Mo	TiO2%	Fe2O3%
	Detection Limit	2	2	2	2	1.5	12	5	4	3	5	5	4	2	3	3	3	3	2		
J1	Ghassul	16.6	905.1	23.5	221	60.5	384	5	5	2	19	193	166	52	168	46	119	22	2	2.69	13.16
J2	Ghassul	17.8	857.3	24.6	215	59	392	5	5	2	19	192	178	48	168	38	115	22	2	2.65	13.49
J3	Ghassul	24.2	864.1	24.3	230	62.8	374	4	5	0	23	205	182	54	179	48	124	23	2	2.8	13.63
GP12C	SWEIMEH	23.4	900	24.6	206	58.8	359	7	6	0	21	201	164	54	154	48	117	21		2.57	12.8
GP14A	MA'IN	22.1	965	24.8	251	65.3	384	7	5	0	16	202	138	58	153	57	118	24		2.99	13.21
J10	W. Fidan	32.6	1141.9	28.9	342	96.7	686	8	8	0	17	222	237	54	223	60	146	25	3	3.44	14.59
29 *	TAFILA/DANA	27	1092	25	288	85	487	18	0		20	211	392	70	250	73	144			3.243	13.96
J11	W. Feinan	7.5	562.9	18.8	108	18.4	488	3	4	0	21	180	295	60	225	75	107	20	0	1.54	13.17
J61	Safi	9	551.8	17.7	104	17.6	506	25	2	0	20	173	278	58	231	66	100	21	0	1.38	12.7
J64	Safi	9.2	556.2	19.5	109	18.1	325	47	3	0	22	186	304	61	232	69	119	21	0	1.61	13.43
GP2	KERAK	8.8	580	19.6	109	20.8	1242	5	3	0	23	185	315	60	219	75	103	20		1.47	12.77
GP27	Safi	9.2	559	19	103	18.7	446	8	2	0	17	181	263	58	205	68	102	21		1.42	12.17
J62	Safi	12.6	675.9	18.7	136	30.4	322	5	1	2	23	202	296	60	223	58	112	21	0	1.95	12.96
J63	Safi	12.2	630.7	18.6	133	29	253	87	2	1	20	209	303	61	218	77	108	22	0	1.98	12.89
J65	Safi	12.5	681	19.5	141	34.5	384	6	4	0	26	213	320	59	226	62	110	21	0	2.12	13.17
J12	W. Feinan	13.8	581.1	19.9	141	27.5	898	5	3	0	23	197	311	57	226	68	107	22	0	1.93	12.5
24**	W. EL-MUJIB	12	584	23	127	27	261				20	201	227	45	200	51	88			1.97	12.36
GP28	Safi	13.6	656	18.5	132	31.6	284	13	4	0	22	216	316	59	211	53	102	20		1.96	12.55
J5	Ghassul	9.5	450.9	26.4	144	17.9	210	4	2	1	29	218	208	43	69	31	293	23	0	2.11	12.31
J9	Maadi	9.7	422.1	24.2	135	16.3	172	10	2	0	28	228	217	45	70	54	106	23	0	2.08	12.49
J13	Erani	8.9	437.4	24.8	138	16.3	301	4	4	0	26	215	215	43	68	34	99	23	0	2.05	11.87
J38	Abu Matar	9.5	456.2	23.5	132	17.6	426	4	2	2	23	212	208	42	66	58	96	23	0	1.92	11.72
J40	Abu Matar	9.6	609.3	23.2	137	21.4	441	4	3	1	23	204	164	40	51	47	91	25	0	1.85	11.65
GP37	Sal	9.4	406	24.5	134	17.4	152	4	4	0	25	218	207	51	71	54	98	22		2.03	11.98
32	Shuna	8.2	547.5	22.7	147	20.7	478	6	4	3	24	215	259	48	103	49	103	23	0	1.7	11.9
23	WADI 'ARAB	8.6	536.7	22.7	153	21.8	313	2	2	0	22	198	232	44	105	60	92	23	0	1.85	11.61
J31	Shuna	14.1	638.5	29.5	188	34.2	532	8	3	0	28	251	183	51	98	58	115	24	1	2.35	12.63
J42	es-Safadi	11.5	571.5	27.9	205	35.4	363	6	4	1	23	215	113	39	43	40	105	24	0	2.29	12.01
GP10	W. YARMOUK	14.9	761	25.6	174	35.5	363	6	3	0	20	224	213	54	141	68	112	20		2.38	12.25
J35	Abu Matar	6.9	450.4	23.1	138	15	2020	5	1	0	26	202	350	58	209	73	108	18	0	1.78	13.25
J39	Abu Matar	8.3	380.2	24.7	132	17	135	4	1	1	25	227	329	49	166	78	114	21	0	2.05	13.52
J47	Ghassul	7.5	766.3	22.8	117	14.5	172	6	3	0	24	176	309	56	212	64	109	20	1	1.74	13.18
J15	Erani	11.6	647.5	24.4	170	26.2	396	4	4	1	26	219	204	48	87	58	100	23	0	2.46	12.75
J16	Erani	11.2	659.7	22.9	159	24.3	260	5	0	2	23	197	190	48	85	40	96	24	1	2.32	12.33
J66	Shuna	8.6	460.4	23.9	160	21.6	279	6	4	0	25	222	421	57	266	62	125	21	0	1.93	13.85
J29	Shuna	12.1	469.3	23.2	132	21.2	221	5	6	0	19	200	287	55	213	66	97	21	0	1.94	13.28
J44	es-Safadi	5.8	521.5	22.9	135	21.7	196	4	2	0	25	220	233	46	73	44	112	22	1	2	13.45
J45	es-Safadi	10.3	560.4	22.5	145	22.2	229	4	4	0	24	201	108	43	54	42	111	23	0	2.05	12.68
J46	es-Safadi	9.4	556.3	23	144	21.6	260	4	2	2	21	233	139	46	49	53	113	23	0	2.11	12.93
GP36	Sal	16.1	424	24.3	141	22.3	316	3	4	0	22	201	289	59	236	70	91	21		1.69	12.47
J6	Ghassul	9.2	395.5	19.7	121	15.3	200	1	1	1	19	174	312	56	223	52	105	19	0	1.65	12.72
J17	Erani	7.7	333.1	20.1	122	14.4	138	4	2	0	22	188	315	58	239	64	106	19	0	1.73	13.05
67	Shuna	9.3	340.1	21.4	123	14.2	162	5	4	2	24	214	286	50	169	59	118	20	0	1.68	12.27
68	Shuna	7.9	326.9	22.9	118	11.6	169	3	3	0	21	201	312	58	195	56	117	23	0	1.6	12.54
J26	Shuna	3	343.6	23.1	123	13.7	202	3	1	0	26	199	288	55	181	59	120	22	0	1.96	13.45
J27	Shuna	4.7	376.1	21.9	115	11.3	495	2	4	0	23	215	316	55	171	61	109	20	0	1.68	13.12

Table 4: Chemical analyses of new geological samples

Sample ref.		J18	J19	J20	J21	J22	J23	J24	J25
Outcrop		N. of Shuna	N. of Shuna	Adasiyeh	Adasiyeh	W. 'Arab	W. 'Arab	Maqarin	Maqarin
Element/oxide	Detection Limit								
Rb (ppm)	2	7.5	8	7.4	11.3	8.6	8.6	12.5	13.4
Sr	2	494.8	550.8	572.8	553.8	518.9	536.7	966.6	838.4
Y	2	23.6	25.8	25.3	26.5	25.7	22.7	25	24.9
Zr	2	162	162	156	165	166	153	184	184
Nb	1.5	26.7	22.2	23.2	23.3	24.6	21.8	35.7	35.8
Ba	12	329	305	264	261	246	313	372	357
Pb	5	3	5	4	5	4	2	5	4
Th	4	2	4	5	2	4	2	6	6
U	3	0	0	0	3	0	0	2	1
Sc	5	27	24	23	23	23	22	25	23
V	5	193	217	192	200	201	198	195	190
Cr	4	326	208	259	208	242	232	265	274
Co	2	54	49	47	43	49	44	55	58
Ni	3	205	90	110	82	112	105	207	215
Cu	3	61	50	57	53	55	60	61	61
Zn	3	115	102	98	99	104	92	123	125
Ga	3	21	20	22	24	22	23	21	22
Mo	2	0	0	0	0	0	0	1	0
TiO_2%		1.82	2	1.8	1.88	1.97	1.85	2.38	2.37
Fe_2O_3%		13.36	12.12	11.87	11.78	12.56	11.61	13.29	12.92

However we do not have analyses of every flow in the Levant and therefore provenancing cannot be done on an exclusive basis. That is to say, we can find close similarities between artefacts and outcrops, but we are unable to show distinction of an artefact from every other unit within the Levant volcanics. However, even though the ideal of provenancing (in which similarity to source outcrop and dissimilarity from every other outcrop is illustrated) eludes us at present in this area, we can still make useful observations based on the chemistry of the samples. We can group samples chemically to suggest which sites may have been acquiring artefacts made from basalts extracted from the same outcrops, and we can compare them with geographically proximal and archaeologically likely sources. Chemical matches within or close to precision, notwithstanding the provisos noted above, are still an indication of likely source (see Williams-Thorpe and Thorpe 1993: 281).

Grouping the samples chemically

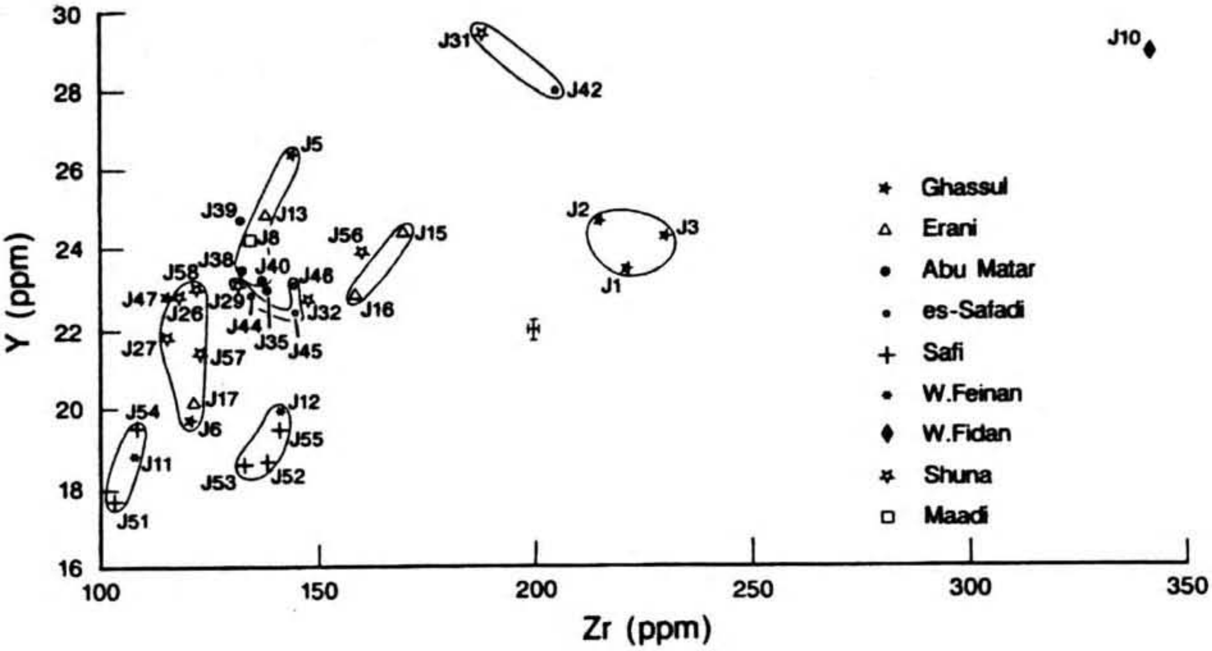
In an initial visual assessment of the chemical data (Table 3), the thirty five archaeological samples were divided into twelve different chemical types, several of which include material from more than one archaeological site. It is therefore likely that the samples studied are from twelve different flows or other geological units. The grouping of the samples can be illustrated for most cases by the generally incompatible and immobile elements Y and Zr (Figure 2), and is reflected in the order of samples in Table 3. Groups are defined as samples whose data are similar within or near precision for stable and/or diagnostic elements including Zr, Y, Nb, Ti and Rb (in most cases this is so for all elements analysed). Differences between groups are often small in absolute terms, but identifiable because precision is generally good. It was noted that Ba, often a relatively mobile element, and Pb are less well correlated with groupings.

Thin-section characteristics, described above, showed J1, J2 and J3 to comprise a distinctive group, and J10 to be distinctive (as in the chemical grouping). J12, slightly distinctive in texture in thin section, is chemically grouped with J51 and J54 which have similar mineral content but more holocrystalline texture.

Provenancing within the Levant basalts

Williams-Thorpe and Thorpe (1993: 296) demonstrated that Fe and Ti abundances in Levant volcanics show some systematic variation according to geographic area, though there were significant overlaps between fields. The addition of more recent data (Figure 3) for outcrops east of the Dead Sea (Sweimeh, Ma'in, Mujib, Kerak) reveals that these volcanics also overlap fields for Tiberias, Jordan plateau (As Shamah plateau) and Syria. However there remain some distinctions – Mujib/Kerak area volcanics are generally lower in Fe and Ti concentrations than Sweimeh/Ma'in volcanics. Sources in the Jaulan are characterized by their high Ti/Fe ratios.

The mineralogically distinctive basanitic volcanics from the Dana/Tafila area south-east of the Dead Sea (not on Figure



Fgure 2: Graph of Y against Zr in archaeological samples, reflecting the chemical groupings discussed in the text. Most groups are enclosed by ellipses; J39, J47 and J35 form one group. J10, J56 and J32 are separate samples which do not group with others. Groups which overlap in terms of Y and Zr are differentiated by other elements (Table 3). The error bar is 1.4% and 1% for Y and Zr respectively (1 σ). Symbols indicate archaeological site as shown on the legend.

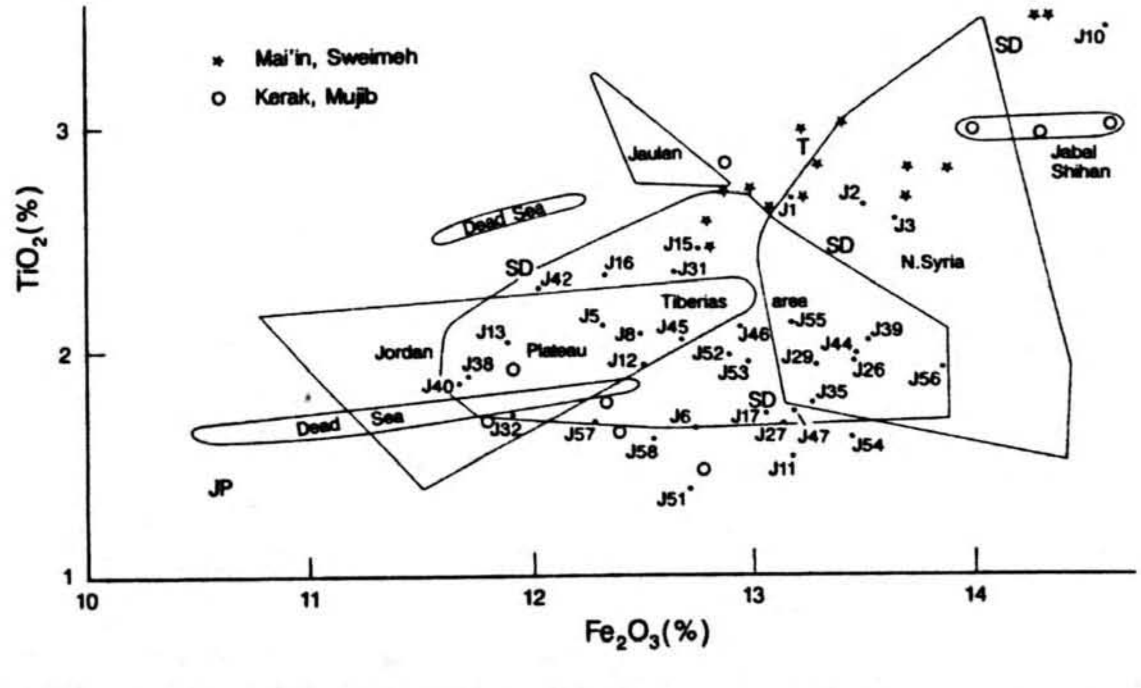


Figure 3: Graph of TiO_2 against Fe_2O_3 in Levant basalts and related rocks, and in new archaeological samples. Fields are based on Williams-Thorpe and Thorpe (1993), but altered to include new geological samples in this report and in Philip and Williams-Thorpe (1993) from the southern Tiberias area. Field boundaries are drawn around all relevant samples for which data are available. Also included is additional data for volcanics from the Sweimeh/Ma'in area and Mujib/Kerak area east of the Dead Sea, from Philip and Williams-Thorpe (1993), Saffarini *et al.* (1987) and Saffarini *et al.* (1985). Jabal Shihan is a volcano in the Mujib area (Saffarini *et al.* 1985). Karameh (Ghor el-Katar) is excluded (see text). T, JP, SD are samples from Tiberias, Jordan Plateau (As Shamah) and south of Dead Sea (Dana/Tafila) areas respectively. Mineralogically distinctive nepheline basanites from south of the Dead Sea are not plotted except for samples in Williams-Thorpe and Thorpe (1993) but are discussed in the text. Archaeological samples (small dots) are numbered as in the Tables. No error bar is plotted on the graph because the data are from disparate sources and subject to varying errors (errors on Open University data are about 5% relative 1σ).

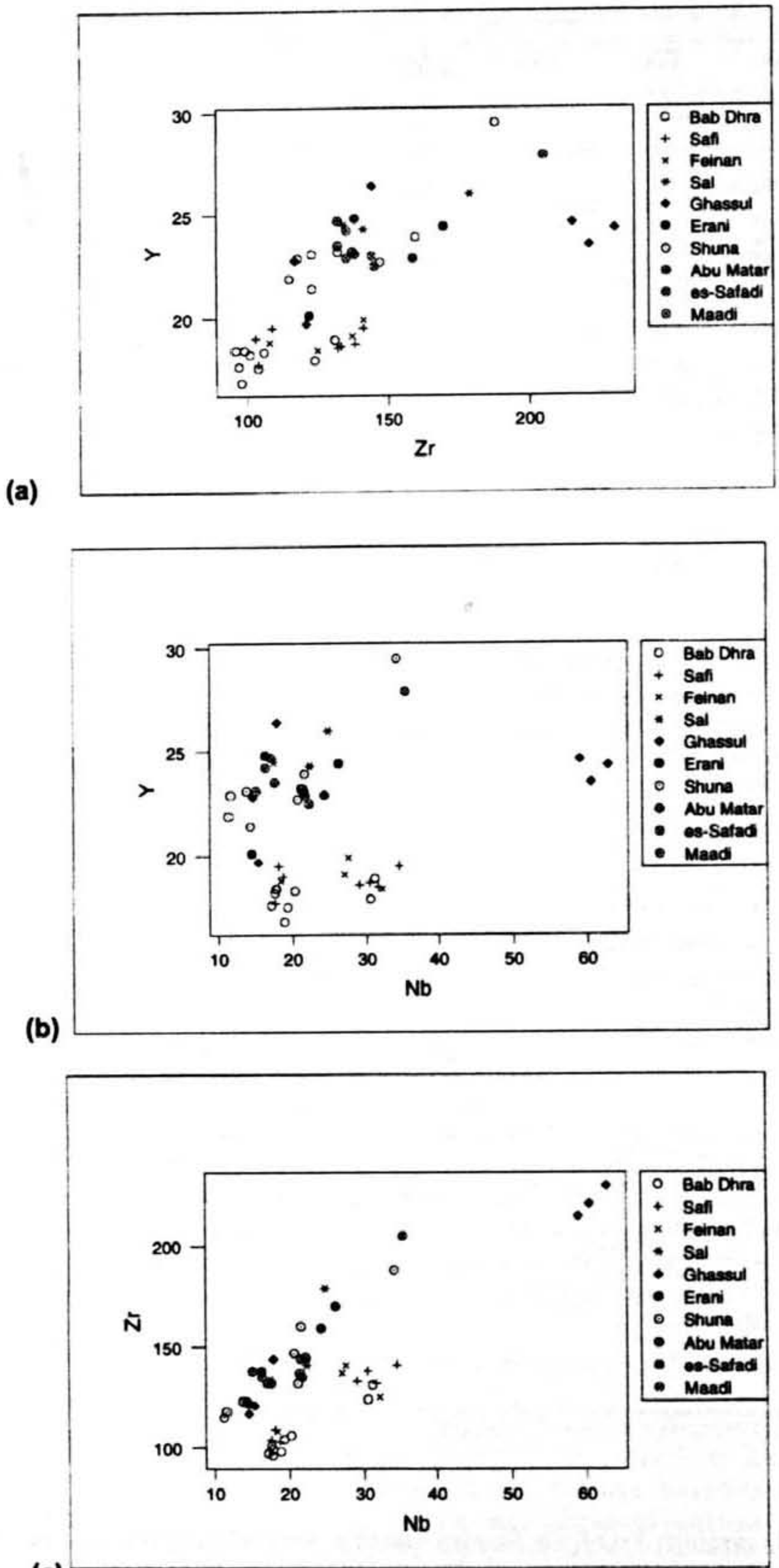


Figure 4: Graphs of (a) Y v Zr, (b) Y v Nb, and (c) Zr v Nb for combined archaeological artefact samples from Philip and Williams-Thorpe (1993) and the present programme (excluding petrographically distinctive phosphorite and basanite specimens). A group of three artefacts from Ghassul is characterized by high concentrations of Zr and Nb: all three are processing tools, and are identified as from local basalt outcrops. Material from sites located south and east of the Dead Sea is characterized by low concentrations of Y, although the latter appears to fall into (at least) two groups distinguished by Nb and Zr. Errors for Y and Zr are as on Figure 3; precision for Nb is 2 % relative 1 σ.

3) include a large range of Ti/Fe ratios but are typically high in Ti (mainly >3% TiO_2), and are also distinguished by high Sr values (often >1000ppm) (Ibrahim and Saffarini 1990; Saffarini *et al.* 1985; 1987).

Nb and Sr concentrations, also used by Williams-Thorpe and Thorpe (1993) for Levant source discrimination, are subject to similar large field overlaps to those shown in Figure 3.

Discussing the samples in the order of the groupings suggested above (see Figure 2), comments may be made on provenance. All artefact analyses were compared with all Levant source data referred to by Williams-Thorpe and Thorpe (1993) and also additional papers referred to by Philip and Williams-Thorpe (1993) and in this paper, including unpublished theses. When comments are made on similarities between artefacts and potential sources, it means that all the papers referred to offer no equally close analytical parallel. Note that similarities between samples from different sites, and with samples analysed by Philip and Williams-Thorpe (1993) are summarized below in Table 5.

It is undoubtedly the case that the expansion of the source database for the Levant has made more apparent areas of overlap (in terms of chemical composition) between the basalts of different regions. This makes precise provenancing of some artefacts difficult, a point reflected in the following discussion in which the limitations of Figure 3 are admitted. The use of multi-variate statistics may enhance source discrimination, but given the slight inconsistencies between the exact sets of trace elements measured by different studies of the various geological outcrops, this was deemed beyond the scope of the present project (but see future directions for research below).

J1, J2, J3. These three high-Zr samples fall into the field of northern Syria and within the cluster of geological specimens from Sweimeh/Ma'in on Figure 3. Since these samples were found at the site of Teleilat Ghassul from which the Sweimeh outcrop is visible, and the Syrian basalts lie some 450km to the north, the Sweimeh/Ma'in area is regarded as the more likely source. Comparison with available source analyses from Sweimeh/Ma'in area showed close similarity with samples 12C and 14A (Sweimeh and Ma'in respectively, from Philip and Williams-Thorpe 1993, quoted in Table 3 of this report). Sample 14A gives a slightly better match in terms of Fe and Ti, but because of the real (*i.e.* greater than precision) range observed in both outcrop and artefact groups it is not possible to be certain whether the artefacts originated at Sweimeh or Ma'in, although the former is more accessible from the site.

Sample J10. This sample from Wadi Fidan is readily distinguished from all others studied here, both in chemistry (Zr 342ppm, Sr 1142ppm, TiO_2 3.44%, FeO_2 14.59%) and in mineralogy (nepheline, fresh olivine, no feldspar). While on Figure 3, it lies near a sample from south of the Dead Sea, and near two Sweimeh/Ma'in samples, in composition it shares the distinctive characteristics of the basanitic rocks of the Dana/Tafila area noted above (high Ti, Sr, also higher Rb than other samples indicating higher K and more alkalic tendency). The composition of a similar rock from the Dana/Tafila area is given in Table 3 (Saffarini *et al.* 1987: 197, analysis no. 29 from west of Jurf ad-Darawish).

J11, J51, J54. These samples, from sites in the southern Ghor/northern Wadi Arabah, lie outside the Tiberias field on Figure 3 and near a sample from the Mujib/Kerak group. Their composition is paralleled extremely closely by a source sample from Kerak analysed by Philip and Williams-Thorpe (1993, sample GP2), and also by a series of artefacts from Bab edh-Dhra' and Safi studied in that paper (see Figures 4a-c). One of those samples, GP27 from Safi, is quoted in Table 3 together with GP2. Very similar rocks from the Mujib area are included in unpublished analyses of el-Jabbar (1989). These do not provide as exact a match as GP2 so that is still regarded as more representative of likely source.

J52, J53, J55, J12. These samples originate from sites in the southern Ghor/northern Wadi Arabah. Figure 3 is unhelpful here, as these samples lie in overlapping fields on that diagram. However, they do match exactly within or very near precision two samples previously analysed from Safi and Bab edh-Dhra' (Philip and Williams-Thorpe 1993, samples GP23 and GP28; see Figures 4a-c). GP23 and GP28 and J52 etc. are all likely to originate in the Mujib area and a similar rock sample from Mujib no. 24 from El-Jabbar (1989), is quoted in Table 3 together with one of the previously analysed samples, GP28. It was noted above that sample J12 has a slightly different texture from the majority of artefacts analysed for this work, being less holocrystalline than other samples. The composition of the sample however remains diagnostic in assigning the artefact to a part of the Mujib area, perhaps a different outcrop or part of an outcrop.

J5, J8, J13, J38, J40. J40 is a less certain member of this group because it has higher Sr abundance. However, Sr can vary with major mineral content in small sub-samples of artefacts, while those elements expected to be in the sample groundmass (and therefore less subject to sample size-related error) such as Zr, Y and Nb are similar in J40 to other group members. The group contains members from Maadi, sites in the Wadi Beersheba and Teleilat Ghassul. While the finds are spatially dispersed, the analytical similarities suggest use of the same basalt unit for these artefacts. In this context it is worth stressing that that all five samples are from Chalcolithic, rather than EB I contexts. That from Tell Erani is in fact the sole specimen of Chalcolithic date from the site included in the present study. All other samples from the site analysed here were from EB I contexts and were chemically different.

The group lies in overlapping fields in Figure 3 but is well matched by an archaeological sample collected from the surface of the unexcavated Chalcolithic settlement of Sal, located on the north Jordan plateau, with easy access to local basalt outcrops (Philip and Williams-Thorpe 1993: GP37 quoted in Table 3 of this report).

Site	Sample ref.	Artefact type	Likely source area of group
Ghassul	J1	Grinder/rubber fragt	Sweimeh or Ma'in
	J2	Grinder/rubber fragt	
	J3	Grinder/rubber fragt	
Wadi Fidan 4	J10	Vessel, curve sided	Tafila/Dana area
Wadi Feinan	J11	Vessel	Kerak
Safi	J51	Vessel	
Safi	J54	Vessel	
Safi	GP27	Bowl, 4? handled	
Bab edh-Dhra'	GP18	Bowl	
Bab edh-Dhra'	GP19	unknown	
Bab edh-Dhra'	GP20	Bowl	
Bab edh-Dhra'	GP21	Bowl	
Bab edh-Dhra'	GP24	Bowl	
Bab edh-Dhra'	GP25	Bowl	
Bab edh-Dhra'	GP26	Bowl	
Safi	J52	Vessel	El-Mujib
Safi	J53	Vessel	
Safi	J55	Vessel	
Safi	GP28	Vessel	
Bab edh-Dhra'	GP23	Large bowl	
Wadi Feinan	J12	Rubber type tool	
Ghassul	J5	Bowl	North Palestine/Jordan
Maadi	J8	Stone ring	around Sal or south-east
Erani	J13	Bowl, pedestal base	of Lake Tiberias ?
Abu Matar	J38	Vessel	
Abu Matar	J40	Vessel	
Sal	GP37	Bowl	
Shuna	J32	Mortar type vessel	Wadi Arab
Shuna	J31	Vessel	Wadi Yarmouk
es-Safadi	J42	Vessel	
Abu Matar	J35	Vessel	North Palestine/Jordan
Abu Matar	J39	Vessel	possibly area south-east
Ghassul	J47	Vessel	of Lake Tiberias
Erani	J15	Vessel bearing knobs	?
Erani	J16	Vessel base	
Shuna	J56	Vessel	? but not Dead Sea area
Shuna	J29	Vessel	? Possibly area south-
es-Safadi	J44	Vessel	east of Lake Tiberias
es-Safadi	J45	Vessel	
es-Safadi	J46	Vessel	
Ghassul	J6	Vessel	?
Erani	J17	Bowl, four handled	
Shuna	J57	Vessel	
Shuna	J58	Vessel	
Shuna	J26	Vessel	?
Shuna	J27	Vessel	

Table 5: Archaeological sites, samples and artefact types from Jordan, Palestine and Egypt arranged by their likely geological provenances.

J32. This sample from Tell esh-Shuna is matched closely by material from the nearby Wadi 'Arab, and sample J23 is quoted in Table 3.

J31, J42. These two higher-Y samples, from Tell esh-Shuna and es-Safadi, fall within the Tiberias or Jordan plateau basalts on Figure 3 (but also near a sample from south of the Dead Sea). They are closely matched by sample GP10 (from the mouth of the Wadi Yarmouk some 10 km north of Tell esh-Shuna (Philip and Williams-Thorpe 1993: 57), quoted in Table 3 of this paper.

For all the above groups, analytical matches within or near precision could be found. For the groups below, no such matches could be identified and provenancing suggestions are accordingly less geographically precise.

J35, J39, J47. These samples are from the Chalcolithic sites of es-Safadi and Teleilat Ghassul. J47 is an uncertain member of the group because of higher Sr (which could however be the result of greater mineral inhomogeneity and less representative analysis; *cf.* above, sample J40). Anomalously high Ba in J35 is unlikely to be a primary compositional characteristic; no convincing reason was found for this abundance, and sample contamination or inclusion of nearby (secondarily) mineralized material remain possibilities. The samples lie within Tiberias and Northern Syria fields on Figure 3 and away from Dead Sea volcanic areas. Sample GP37 from the Chalcolithic site of Sal (see above) shows close similarity within or near precision for several diagnostic elements, but differs in particular in Fe concentration. GP37 is quoted earlier in Table 3. All three samples come from Chalcolithic contexts, are non-local to the sites at which they were recovered, and appear to originate from basalt outcrops in the north.

J15, J16. These two samples from EB I contexts at Tell Erani lie within the Tiberias and near the Jordan Plateau fields on Figure 3 and also (J15) near samples from Ma'in and Sweimeh. However, they are clearly distinguished from the latter sources on the values for Nb. No exact source identity was found, although once again a northern source appears likely.

J56. This sample from Tell esh-Shuna cannot be matched with an outcrop, but Figure 3 suggests an origin within the Tiberias basalts or those from more distant Northern Syria, the latter being less likely on archaeological grounds. It is unlikely to come from sources further south.

J29, J44, J45, J46. Figure 3 suggests that these, which come from es-Safadi and Tell esh-Shuna, are unlikely to originate within the Dead Sea basalts. GP36 from the archaeological site of Sal (Philip and Williams-Thorpe 1993) offers an excellent compositional parallel for many trace elements including Nb, Y and Zr (Table 3) but differs beyond precision for example in Ti and Rb concentrations. All four samples come from contexts of Chalcolithic date

J6, J17, J57, J58. This group which includes material from Tell esh-Shuna, Teleilat Ghassul and Tell Erani (EB I), lies mainly within the Kerak, Mujib and Tiberias area basalts on Figure 3, but the graph does not allow distinction from all Jordan Plateau rocks. However, the samples appear to be differentiated from the Mujib and Kerak material examined by the present authors on Nb and Sr concentrations (Philip and Williams-Thorpe 1993).

J26, J27. The samples from Tell esh-Shuna are ambiguous on Figure 3 (Tiberias, Syria, near a sample from South of the Dead Sea). They differ from the previous group mainly by their lower Rb concentrations and slightly higher Zr/Nb ratios. No compositional parallel was found, but like the previous group these samples differ from the Mujib/Kerak material previously studied by the authors.

Summary and discussion of provenances

Table 5 summarizes the geological provenances, where determined, of the archaeological samples analysed for this report, and also shows samples with similar geological provenance analysed by Philip and Williams-Thorpe (1993). Artefact type is shown in order to highlight any correlation between rock source and product. Sites and hypothesized patterns of resource acquisition are indicated in Figure 5. For ease of reference, combined plots of the values for the key trace elements Y, Zr and Nb from artefactual samples in the current study, and those previously published (Philip and Williams-Thorpe 1993) are presented in Figures 4a-c. The analytical data are presented in Table 3 here and in Philip and Williams-Thorpe (1993: Table 4).

Sites located east and south of the Dead Sea

Previous work (Philip and Williams-Thorpe 1993: 58-9) had suggested that the material from several sites in this area originated from sources in the vicinity of the Kerak plateau or the Wadi Mujib, but that material from more than one source appeared to have been employed. In order to ensure a more even balance between the various sites in this area additional samples were taken from material collected from recently looted EB I tombs at Safi, and from the surface of EB I sites in the Wadis Feinan and Fidan. One of the main feeders of these wadi systems is Wadi Dana, which originates at the bottom of the nepheline basanite outcrops immediately east of Dana village (Figure 1), and which carries material from this source down into the wadi systems below. Investigation was intended to identify the degree of relationship between the material in use at these three locations, and to provide additional data to explore the status of the Dana outcrop as a potential source for basalt in use at sites in the Wadi Feinan.

Including material examined previously (Philip and Williams-Thorpe 1993: GP29 and GP30), five different artefacts collected from sites in the Wadis Feinan and Fidan have now been analysed. One sample (J10), a mortar-type vessel with curved-sides, belonging to the category of processing tools rather than bowls (see above) showed the distinctive mineralogy characteristic of the basanitic rocks of the Dana/Tafila area, which occur as cobbles in the local wadi bed, thus confirming the use of this readily available material. However, the other four samples from sites in this area were from flat-based bowls with splayed sides and are chemically extremely similar to artefacts occurring at Safi and Bab edh-Dhra'. All four samples taken from bowls from these three sites which have been analysed are characterised by consistently low levels of Y (<20ppm). However, examination of the distribution of other trace elements indicates that the material from these sites falls into (at least) two broad chemical groups which can be differentiated from each other by Nb and Zr among other elements (see Figures 4a-c, Table 5). Artefacts from both sub-groups occur at all three locations, arguing for the existence of some sort of common procurement system for bowls (or basalt for bowl production) linking settlements in the lowlands east and south of the Dead Sea.

The artefacts concerned find their closest geochemical parallels at two separate localities among the extensive outcrops in the Mujib/Kerak area (Philip and Williams-Thorpe 1993: 59-60; Table 3 here; El-Jabbar 1989) which are also characterised (with the exception of one sample GP5B) by generally low levels of Y. The association between low levels of Y and the basalts of this area is supported by a recent geochemical study of thirteen fragments of basalt artefacts collected from archaeological sites of various periods located on the Kerak plateau itself (Watts 1997). These revealed low levels of Y (range 11-16ppm) in all but one instance.

Values for the elements Zr and Nb also appear broadly in line with those occurring in the geological samples from this area. The basalt sources in the Wadi Mujib/Kerak area are quite extensive (Figure 1) and the relatively restricted range of values for Zr and Nb occurring within each of the two groups of archaeological samples might suggest the exploitation of basalt from a limited number of locations within this general area, rather than a more casual procurement strategy. Relative chemical variability in the Mujib/Kerak source area is difficult to state with certainty, given the limited number of outcrop samples analysed to date. Data in Philip and Williams-Thorpe (1993) show Zr ranging from 109ppm to 139ppm with one sample of 211ppm (GP5B), and Nb ranging from 20.8ppm to 34.3ppm, with one samples of 51.8ppm (GP5B).

The combination of a concentration upon local basalt in this area, and the absence of similar material from other sites included in the study (see above), argues for the existence in this area of a discrete regional procurement system, for bowls at least. The predominance at sites located within Wadi Feinan of bowls in this basalt over the local basanites is striking. However, the use of local sources for the production of a mortar from Wadi Fidan 4 hints at the possible existence of some locally-based ground stone production, although not on present evidence extending to the manufacture of bowls.

Teleilat Ghassul

Recent excavations at the well-known Chalcolithic settlement of Teleilat Ghassul located immediately north of the Dead Sea (Hennessy 1989; Bourke personal communication) provided an opportunity to examine material of known context from the site. While Ghassul is located within sight of the Sweimeh basalt outcrop, a petrographic examination of two vessels from the site by Ibrahim (personal communication), had suggested that neither was likely to have been produced from Sweimeh basalt, although the raw material was quite suitable. Questions were thus raised concerning the potentially non-optimizing nature (in economic terms) of basalt acquisition. In order to investigate the nature of basalt utilization at Ghassul geochemical analysis of four samples from bowls and three samples from basalt processing tools was undertaken.

In the case of this major Chalcolithic settlement a clear distinction exists between the origin of the grinding tools, all three of which appear to derive from local basalt sources and the four samples taken from bowls, none of which were produced from local basalts (see above). One of the latter was identified as phosphorite, a dark sedimentary rock, the presence of which among the bowls from Ghassul was already known (Goren 1991). The absence of such vessels from any of the other sites in Jordan included in our study appears to confirm Goren's (1991) view that these do not originate in Jordan, but in central Palestine. The remaining bowls were composed of olivine basalts from more distant sources, most likely somewhere in northern Palestine or Jordan. While there is evidence for ground stone manufacturing, at or near to Ghassul, this does not appear to have included the production of bowls, unless these were produced locally utilizing raw materials acquired from sources located both to the north (basalt) and west (phosphorite).

Northern Jordan

Artefactual samples from Tell esh-Shuna at the northern end of the Jordan Valley were collected along with a number of specimens from the local geological outcrops in order to examine basalt exploitation at a northern site with ready access to the requisite materials. These were obtained from early Chalcolithic and EB I contexts and were analytically compatible with the local sources of Wadi 'Arab, Wadi Yarmouk and perhaps also the north Jordan plateau. The absence of fresh olivine in these samples would appear to exclude the Jaulan and the Maqarin areas as potential sources, suggesting origins at various locations within the outcrops around Tiberias, the North Jordan Valley, or the North Jordan plateau. Material examined from this site, and Sal on the plateau (Philip and Williams-Thorpe 1993) thus appears generally compatible with production from northern basalts. On present evidence there is no indication of the presence at northern sites of material made from the basalts of central or southern Jordan.

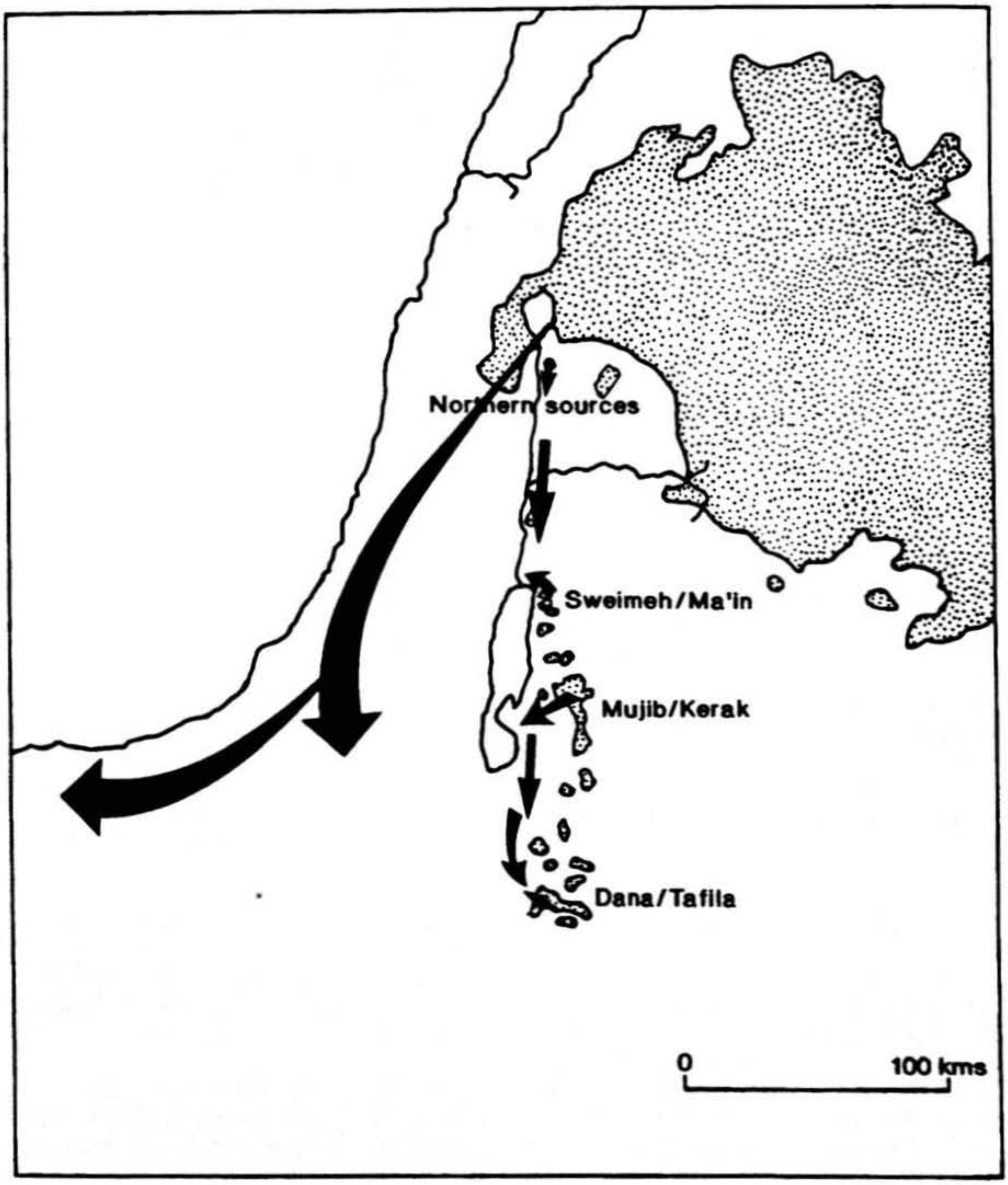


Figure 5: Reconstruction of patterns of basalt procurement. The extensive distribution of material from northern sources, contrasts with the more spatially restricted distribution of basalt from the Sweimeh/Ma'in and Mujib/Kerak areas.

Southern Palestine and Egypt

While all of the sites discussed above were located within easy reach of outcrops of fine-grained, non-friable basalt, the evidence for medium-range basalt procurement is clearest in the case of settlements in southern Palestine, an area devoid of basalt suitable for bowl manufacture (Amiran and Porat 1984: 14). The analytical programme therefore included samples from artefacts recovered at the Chalcolithic settlements of Abu Matar and es-Safadi in the Wadi Beersheba, and from both the Chalcolithic and EB I periods at Tell Erani. The material from Tell Erani and sites in the Wadi Beersheba appears to derive from several different sources, and all those sources for which provenance could be suggested appear compatible with an origin in northern Palestine or Jordan. This would argue against the view (Perrot 1955: 84; Gilead and Goren 1989: 12; Philip and Williams-Thorpe 1993: 61) that basalt from sites in southern Palestine originated at the most proximate sources, *i.e.* those in south-central Jordan.

Maadi

Given the growing evidence for links between Egypt and southern Palestine during the earlier fourth millennium BC (*e.g.* Van den Brink 1992; Harrison 1993; Levy 1995b; Levy *et al.* 1997), it was decided to extend the project to include a limited sample of material from the 1930's excavations at Maadi near Cairo. The site has produced fragments of stone vessels in a variety of forms. Bowls of Type 5D have good stylistic parallels among the material from fourth millennium Palestine (Rizkana and Seeher 1988: 57), and were made from a basalt distinctly different from that employed for vessels in more traditional Egyptian shapes. Petrographic studies indicated that Type 5D vessels were made of olivine basalt, most probably originating in the Levant (Porat and Seeher 1988: 217; Klemm quoted in Rizkana and Seeher 1988: 57).

Unfortunately no samples from these vessels were available which were sufficiently large to permit analysis. Also reported from the site was a group of perforated discs, made from basalt which was visually similar to that used for the bowls. Possibly to be interpreted as spindle-whorls, these are distinctive in terms of typology, raw material and spatial distribution, and are seen as foreign to the Egyptian artefact repertoire (Rizkana and Seeher 1988: 52, Plate 95: 17-22). The sample analysed from Maadi investigated for this paper was taken from a disc which had previously been studied petrographically by both Porat and Klemm (Porat and Seeher 1988: 17; Klemm quoted in Rizkana and Seeher 1988: 57) both of whom assigned the rock to a source in the southern Levant. Chemical analysis now suggests that this artefact can be assigned to a group including samples from the Chalcolithic sites of Ghassul and those in the Wadi Beersheba, and which can be assigned a northern origin.

Artefacts within this group were made from a basalt similar to that employed for objects recovered from an unexcavated Chalcolithic settlement at Sal on the north Jordan plateau. The presence of artefacts from a single basalt unit, most probably of northern origin, at Ghassul, at sites in southern Palestine, and Egypt, provides evidence for the interaction networks which may have underpinned the well documented spatial homogeneity of the material culture of the developed Chalcolithic (Joffe 1993: 35-37). Vessels in a different type of basalt, but also of likely northern origin, were also present at Ghassul and at Abu Matar. The lack of basalt debris from sites in the Wadi Beersheba (Perrot 1955: 78) suggests that the unit of transport was the complete vessel rather than blocks of raw material, suggesting the existence of a number of specialised production centres in the north. The existence of another, as yet unsourced, type of basalt appearing at Tell esh-Shuna, Erani and Ghassul provides further evidence for an important north-south axis, connecting northern Palestine and Jordan with the Jordan Valley, and south-central Palestine. The apparent absence of central or southern Jordan from this pattern is striking.

Discussion of archaeological implications and conclusions

Although the total number of artefacts examined from any single site was limited, consideration of the chemical data should permit some assessment of the degree of variability within and between artefactual basalts occurring at the various sites. This will allow an impression to be gained of the extent to which individual sites were acquiring basalt artefacts made from single or multiple sources, and thus the likely complexity of procurement systems. A number of points emerge from the foregoing.

1. The evidence indicates the existence of a spatially restricted system for the production and distribution of basalt vessels involving sites located east and south of the Dead Sea. This involved the use of basalts originating in the Mujib/Kerak area, that is within this region. There is currently no evidence for the presence at these sites of basalt from more distant sources.

2. Bowls manufactured using material from northern basalt outcrops appear widely in the north, but their distribution extends to include sites in the Jordan valley, southern Palestine and Egypt. These appear to be absent from sites located east and south of the Dead Sea.

3. There is enough preliminary evidence to argue for the existence of different systems for the procurement of bowls and other ground stone artefacts, although a degree of inter-regional variation in distribution mechanisms is likely. At Ghassul there is evidence for the use of artefacts in both local and imported basalts, with local raw materials used for processing tools while bowls were acquired from more distant sources. Provisional evidence from Wadi Feinan (see above) and Tell Abu Hamid (Ibrahim personal communication) suggests that this situation was not unique to Ghassul, and that we would should envisage individual ground stone assemblages as resulting from the operation of multiple processes. Not only does there appear to be a clear difference between the procurement of basalt bowls and that of the rock employed for the manufacture of processing tools, bowls themselves were produced and distributed through

several distinct networks. Moreover, these networks appear to have functioned at rather different spatial (and perhaps temporal?) scales.

4. The existence at both northern and southern sites of material in a variety of compositions may simply be a function of the size and complexity of the basalt outcrops in the region. However, the recognition of a number of apparently consistent compositional groups suggests that basalt procurement was far from being a random process. Rather, this is indicative of the procurement of basalt from a restricted number of quite specific sources, a point which would, we suspect, be clarified by the compilation of a larger database of artefactual samples. Note how the greater number of analyses now available from sites east and south of the Dead Sea as compared to our previous study (Philip and Williams-Thorpe 1993) has clarified an apparent concentration upon basalt falling into two main compositional groups (Figures 4a-c).

The evident complexity of the patterning is almost certainly in part attributable to the fact that the dataset is a palimpsest, arising from the combined operation at individual sites of several spatially and temporally distinct procurement systems. The fact that several of the most striking, and spatially extensive, compositional groups appear to show chronological integrity supports this view. Another potential complication arises from the likely pattern of vessel movement. Our evidence represents only the final deposition of what were very durable artefacts. Individual bowls may well have had complicated lives, and been the subject of multiple transactions, before finally entering the archaeological record.

5. With the exception of Teleilat Ghassul, phosphorite vessels do not appear at sites in Jordan, confirming Goren's (1991) suggestion that these represent the operation of a spatially restricted system of production and procurement in south-central Palestine. This view seems all the more likely in the light of the new evidence for a similarly localised bowl procurement system on the east side of the Dead Sea. Taken together these stress yet again the complex structures which underpinned the production and distribution of certain categories of artefact.

It is clear from the above discussion that, as in the case of other classes of material, different types of basalt artefact were acquired by rather different mechanisms. Thus the production and distribution of ground stone artefacts is revealed as a complex and multi-faceted process, most likely embedded within a variety of socio-economic relationships. Basalt, hitherto seen as a rather intractable material with little analytical potential, is revealed as constituting one more element within a network of complex, cross-cutting procurement systems involving a variety of resources, only some of which may have been susceptible to control by incipient elites.

Future directions for research

Since there is now a greater number of source analyses available than for previous discrimination studies for this area (Williams-Thorpe and Thorpe 1993; Williams-Thorpe *et al.* 1991) it will be useful for future studies to establish a computer database for source analyses. This will allow the possibility of quantified statistical comparison of artefacts and sources. However, problems remain, in particular the uneven availability of data with regard to the different geological outcrops, and the concomitant uncertain extent of within-source variation and between source overlaps, in terms of element composition. It may be possible to tackle the latter through further source analysis, in combination with variables such as geological dating (*e.g.* Weinstein-Evron *et al.* 1995), allowing a finer assessment of the potential source materials within individual regions. From an archaeological standpoint, we require the investigation of larger groups of artefacts from individual sites, with sampling strategies designed to cover a broad range of artefact types, and to allow an assessment of diachronic variability in basalt utilization. The direction of research along such lines would allow the realization of the full potential of basalt as an indicator of interaction between human groups.

Acknowledgements

This work was supported by a grant from the British Academy Fund for Applied Archaeological Science (Ref. APN2164) which is gratefully acknowledged. X-Ray fluorescence analyses were provided by the Department of Earth Sciences at the Open University (Mr J. S. Watson and Dr P. C. Webb). We are very grateful to Mr John Taylor (Open University) for drawing Figures 2 and 3 and Mrs Carrie Philip for producing Figures 1 and 7. Material from Tell esh-Shuna and geological samples from Jordan were made available with the kind permission of Dr Ghazi Bisheh, Director General of the Department of Antiquities of Jordan, whose help and support in this project is much appreciated. Thanks are also due to the following scholars who kindly provided artefactual samples for analysis: Dr R. Adams (Wadi Fidan), Dr S. Bourke (Ghassul), Dr B. Brandl (Tell Erani), Dr C. Commenge (Abu Matar and Safadi), Dr J. Seeher (Maadi). Prof J. Mattingly, Director of the Kerak Resources Project, kindly drew our attention to the unpublished data of Watts (1997). None of those listed is responsible for the views expressed above.

References

Adams, R., and Genz, H., 1995, Excavations at Wadi Fidan 4, a Chalcolithic village complex in the copper ore district of Feinan, southern Jordan, *Palestine Exploration Quarterly*, **127**, 8-20.

Amiran, R., and Porat, N., 1984, The basalt vessels of the Chalcolithic period and Early Bronze Age, *Tel Aviv*, **11**, 11-19.

Barberi, F., Capaldi, G., Gasperini, P., Marinelli, G., Santacroce, R., Scandone, R., Treuil, M., and Varet, J., 1980, Recent basaltic volcanism of Jordan and its implications on the geodynamic history of the Dead Sea shear zone, in *Report of International Meeting Roma 1979, Atti dei Convegni Lincei, Geodynamic Evolution of the Afro-Arabian Rift System*, 667-684, Accad. Nat. dei Lincei, Rome.

Barrett, J., 1994, *Fragments from antiquity: an archaeology of social life in Britain, 2900-1200 BC*, Blackwell, Oxford.

Bender, F., 1968, *Geologie von Jordanien*, Gebrüder Borntraeger, Berlin.

Betts, A. V. G., 1991, *Excavations at Jawa 1972-1986*, Edinburgh University Press, Edinburgh

Braun, E., 1985, *En Shadud: Salvage Excavations at a farming community in the Jezreel Valley, Israel*, British Archaeological Reports, International Series **249**, BAR , Oxford.

Braun, E., 1990, Basalt bowls of the EB I horizon in the southern Levant, *Paléorient* , **16**, 87-96.

Braun, E., 1997, *Yiftah'el. Salvage and rescue excavations at a prehistoric village in Lower Galilee, Israel*, Israel Antiquities Authority Reports, **2**, Israel Antiquities Authority, Jerusalem.

Burdon, D. J., 1959, *Handbook of the geology of Jordan*, Government of the Hashemite Kingdom of Jordan, Amman.

Commenge-Pellerin, C., 1987, *La poterie d'Abou Matar et de l'Ouadi Zoumeili (Beershéva) au IVe millénaire avant l'ère chrétienne*, Les cahiers du Centre de recherche français de Jérusalem, **3**, Association Paléorient, Paris.

Commenge-Pellerin, C., 1990, *La poterie de Safadi (Beershéva) au IVe millénaire avant l'ère chrétienne*, Les cahiers du Centre de recherche français de Jérusalem, **5**, Association Paléorient, Paris.

Dorrell, P., 1983, Stone vessels, tools and objects, in *Excavations at Jericho V. The pottery phases of the Tell and other finds* (ed. K. M. Kenyon, and T. A. Holland), 485-575, British School of Archaeology at Jerusalem, London.

El-Hinnawi, E. E., 1965. Petrographical and geochemical studies on Egyptian (U. A. R.) basalts, *Bulletin Volcanologique*, **28**, 283-292.

El-Hinnawi, E. E., and Abdel Maksoud, M. A., 1968, Petrography of Cenozoic volcanic rocks of Egypt (U. A. R.), *Geologische Rundschau*, **57**, 879-890.

El-Hinnawi, E. E., and Abdel Maksoud, M. A., 1972, Geochemistry of Egyptian Cenozoic volcanic rocks, *Chemie der Erde*, **31**, 94-112.

El-Jabbar, D. Y. M. A., 1989, *Petrology and geochemistry of the Quaternary basalts of Wadi el-Mujib and Wadi Heidan, Central Jordan*, unpublished MSc thesis, University of Jordan.

Gilead, I., and Goren, Y., 1989, Petrographic analyses of fourth millennium B.C. pottery and stone vessels from the northern Negev, Israel, *Bulletin of the American Schools of Oriental Research*, **275**, 5-14.

Goren, Y., 1991, Phosphorite vessels of the 4th millenium BC in the southern Levant: new data, new interpretations, *Journal of the Israel Prehistoric Society*, **24**, 102-111.

Goren, Y., 1995, Shrines and ceramics in Chalcolithic Israel: The view through the petrographic microscope, *Archaeometry*, **37**, 285-305.

Goren-Inbar, N., Perlman, I., and Heimann, A., 1986, Chemical mapping of basalt flows at Palaeolithic sites, *Archaeometry*, **28**, 89-99.

Govindaraju, K., Potts, P. J., Webb, P. C., and Watson, J. S., 1994, 1994 report on Whin Sill dolerite WS-E from England and Pitscurrie microgabbro PM-S from Scotland: assessment by one hundred and four international laboratories, *Geostandards Newsletter*, **18**, 211-300.

Greenberg, R., and Porat, N., 1996, A third millennium levantine pottery production center: typology, petrography and provenance of the metallic ware of northern Israel and adjacent regions, *Bulletin of the American Schools of Oriental Research*, **301**, 5-24.

Gvirtzman, G., and Buchbinder, B., 1969, Outcrops of Neogene formation in the central and southern coastal plain, Hashephele and Beer Sheva regions, Israel, *Geological Survey of Israel Bulletin*, **50**, 1-52.

Harrison, T. A., 1993, Economics with an entreprenurial spirit: Early Bronze Age trade with late predynastic Egypt, *Biblical Archaeologist*, **56**, 81-92.

Hauptmann, A., Begemann, F., Heitkemper, E., Pernicka, E., and Schmitt-Strecker, S., 1992, Early copper produced at Feinan, Wadi Araba, Jordan: The composition of ores and copper, *Archaeomaterials*, **6**, 1-33.

Hennessy, J. B., 1989, Ghassul, in *Archaeology of Jordan. II/1 Field reports, surveys & sites*, (eds. D. Homès-Fredericq and J. B Hennessy), 230-241, Akkadica Supplementum **7-8**, Peeters, Leuven.

Ibrahim, K. M., 1987, *Geochemistry and petrology of some of the basaltic outcrops in central Jordan*, unpublished MSc thesis, University of Jordan.

Ibrahim, K. M., and Saffarini, G. A., 1990, Genesis of the nepheline basanites in Tafila district, Jordan, in *Proceedings of the 3rd Jordanian Geological Conference*, 315-343, Amman.

Joffe, A., 1993, *Settlement and society in the Early Bronze I and II southern Levant*, Sheffield Academic Press, Sheffield.

Joffe, A., and Dessel, J. P., 1995, Redefining chronology and terminology for the Chalcolithic of the southern Levant, *Current Anthropology*, **33**, 507-17.

Levy, T. E., 1993, Production, space and social change in protohistoric Palestine, in *Spatial boundaries and social dynamics: case studies from food-producing societies*, (eds. A. Holl and T. E. Levy), 63-82, International Monographs in Prehistory, Ann Arbor.

Levy, T. E., 1995a, Cult, metallurgy and rank societies - Chalcolithic, in *Archaeology of society in the Holy Land* (ed. T. E. Levy), 226-243, Leicester University Press, Leicester.

Levy, T. E., 1995b, New light on King Narmer and the Protodynastic Egyptian presence in Canaan, *Biblical Archaeologist*, **58**, 26-36.

Levy, T. E., Alon, D., Smith, P., Yekutieli, Y., Rowan, Y., Goldberg, P., Porat, N., van den Brink, E. C. M., Witter, A. J., Golden, J., Grigson, C., Kansa, E., Dawson, L., Holl, A., Morena, J., and Kersel, M., 1997, Egyptian-Canaanite interaction at Nahal Tillah, Israel (*ca* 4500-

3000 B.C.E.): An interim report on the 1994-95 excavations, *Bulletin of the American Schools of Oriental Research*, **307**, 1-52.

Levy, T. E., and Shalev, S., 1989, Prehistoric metalworking in the southern Levant: archaeometallurgical and social perspectives, *World Archaeology*, **20**, 352-372.

Pearce, J. A., 1982, Trace element characterization of lavas from destructive plate boundaries, in *Andesites: orogenic andesites and related rocks* (ed. R. S. Thorpe), 525-548, John Wiley and Sons, Chichester.

Perlès, C., 1992, Systems of exchange and organization of production in Neolithic Greece, *Journal of Mediterranean Archaeology*, **5**, 115-164.

Perrot, J., 1955, Excavations at Tell Abu Matar, near Beersheba, *Israel Exploration Journal*, **5**, 73-84.

Philip, G., and Williams-Thorpe, O., 1993, A provenance study of Jordanian basalt vessels of the Chalcolithic and Early Bronze Age I Periods, *Paléorient*, **19**, 51-63.

Philip, G., and Rehren, T., 1996, Fourth millennium BC silver from Tell esh-Shuna, Jordan: archaeometallurgical investigation and some throughts on ceramic skeuomorphs, *Oxford Journal of Archaeology*, **15**, 129-150.

Porat, N., and Seeher, J., 1988, Petrographic analysis of pottery and basalt from predynastic Maadi, *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo*, **44**, 215-228.

Potts, P. J., and Webb, P. C., 1992, X-ray fluorescence spectrometry, *Journal of Geochemical Exploration*, **44**, 251-296.

Rehren, T., Hess, K., and Philip, G., 1996, Auriferous silver in Western Asia: ore or alloy? *Historical Metallurgy*, **30**, 1-10.

Rehren, T., Hess, K., and Philip, G., 1998, Fourth millennium BC copper metallurgy in northern Jordan: the evidence from Tell esh-Shuna, in *The Prehistory of Jordan, II. Perspectives from 1997*, (eds. H.-G. Gebel, Z. Kafafi and G. O. Rollefson), 625-40, Studies in Early Near Eastern Production, Subsistence, and Environment, **4**, Berlin.

Rizkana, I., and Seeher, J., 1988, *Maadi: excavations at the Predynastic site of Maadi and its cemeteries conducted by Mustapha Amer and Ibrahim Rizkana on behalf of the Department of Geography, Faculty of Arts of Cairo University, 1930-1953. Vol 2 The lithic industries of the predynastic settlement*, Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen, **65**, von Zabern, Mainz am Rhein.

Rosen, S. A., 1993, Metals, rocks, specialization and the beginning of urbanism in the northern Negev, in *Biblical Archaeology Today 1990: pre-congress symposium supplement - population, production and power* (eds. A. Biran and J. Aviram), 41-56, Israel Exploration Society, Jerusalem.

Rosen, S. A, 1997, *Lithics after the Stone Age. a handbook of stone tools from the Levant*, Altamira Press, London.

Saffarini, G. A., Nassir, S., and Abed, A. M., 1985, A contribution to the petrology and geochemistry of the Quaternary-Neogene basalts of Central Jordan, *Dirasat*, **12**, 133-144.

Saffarini, G. A., Khoury, H. N., and Raschka, H., 1987, Detection of compositional variations and differentiation trends in Jordanian basalts, *Dirasat*, **14**, 193-210.

Shalev, S., and Northover, P. J., 1987, The Chalcolithic metal and metalworking from Shiqmim, in *Shiqmim I - studies concerning Chalcolithic societies in the northern Negev desert, Israel (1982-1984)* (ed. T. E. Levy), 357-371, British Archaeological Reports, International Series **356**, BAR, Oxford.

Shalev, S., and Northover, P. J., 1993, The metallurgy of the Nahal Mishmar Hoard reconsidered, *Archaeometry*, **34**, 35-47.

Shalev, S., 1994, The change in metal production from the Chalcolithic period to the Early Bronze Age in Israel and Jordan, *Antiquity*, **68**, 630-637.

Stein, G., and Blackman, M. J., 1993, The organizational context of specialised craft production in early mesopotamian states, *Research in Economic Anthropology*, **14**, 29-59.

Tadmor, M., Kedem, D., Begemann, F., Hauptmann, A., Pernicka, E., and Schmidtt-Streckers, S., 1995, The Nahal Mishmar hoard from the Judean Desert: technology, composition, and provenance, *Átiqot*, **27**, 95-148.

Tykot, R. H., 1996, Obsidian procurement and distribution in the central and western Mediterranean, *Journal of Mediterranean Archaeology*, **9**, 39-82.

Van den Brink, E. (ed.), 1992, *The Nile Delta in Transition: 4th-3rd Millennium BC*, Israel Exploration Society, Jerusalem.

Van der Boom, G, 1968, Zur Petrogenese der Plateaubasalte Nordostjordaniens, *Geologische Jahrbuch*, **85**, 489-496.

Wattenmaker, P., 1994, State formation and the organization of domestic craft production at third millennium BC Kurban Höyük, southeast Turkey, in *Archaeological views from the countryside. village communities in early complex societies* (eds. G. Schwartz and S. Falconer), 109-120, Smithsonian Institution Press, Washington D.C.

Watts, B., 1997, *The Kerak resources project: preliminary examination of basalt and basaltware*, unpublished SR. thesis, University of Tennessee.

Weinstein-Evron, M., Lang, B., Ilani, S., Steinitz, G., and Kaufmann, D., 1995, K/Ar dating as a means of sourcing Levantine Epipalaeolithic basalt implements, *Archaeometry*, **37**, 37-40.

Williams-Thorpe, O., 1988, Provenancing and archaeology of roman millstones from the Mediterranean area, *Journal of Archaeological Science*, **15**, 253-306.

Williams-Thorpe, O., Thorpe, R. S., Elliot, C., and Xenophontas, C., 1991, Archaeology, geochemistry and trade of igneous rock millstones in Cyprus during the Late Bronze Age to Roman periods, *Geoarchaeology*, **6**, 27-60.

Williams-Thorpe, O., and Thorpe, R. S., 1993, Geochemistry and trade of eastern Mediterranean millstones from the Neolithic to Roman periods, *Journal of Archaeological Science*, **20**, 263-320.

Wright, K., 1992, A classification system for ground stone tools from the prehistoric Levant, *Paléorient*, **18**, 53-80.

Wright, K. I., Qadi, N., Ibrahim, K., and Mustafa, H., (in press), Ground Stone Artefacts, in *Fouilles à Tell Abu Hamid 1986-87*, (eds. G. Dollfuss and Z. Kafafi), Editions de Recherche sur les Civilisations, Paris.